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Return of Large Scale Upper Stage Rocket Thermal-Vacuum and Altitude Hot-Fire Test Capability to the U.S.

NASA Glenn at Plum Brook Station Sandusky Ohio

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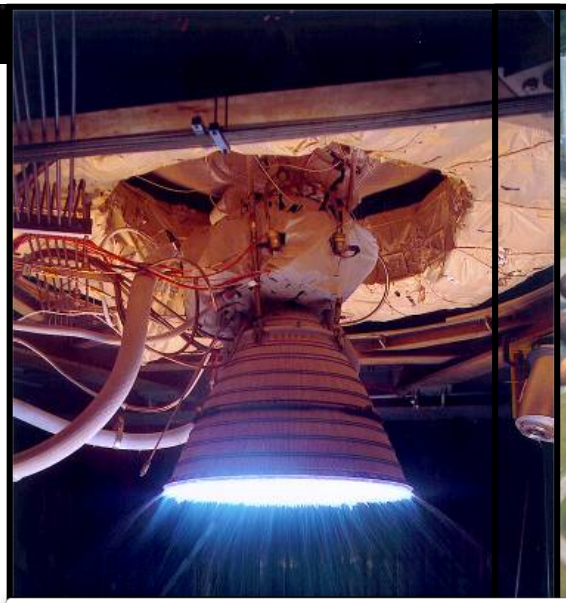
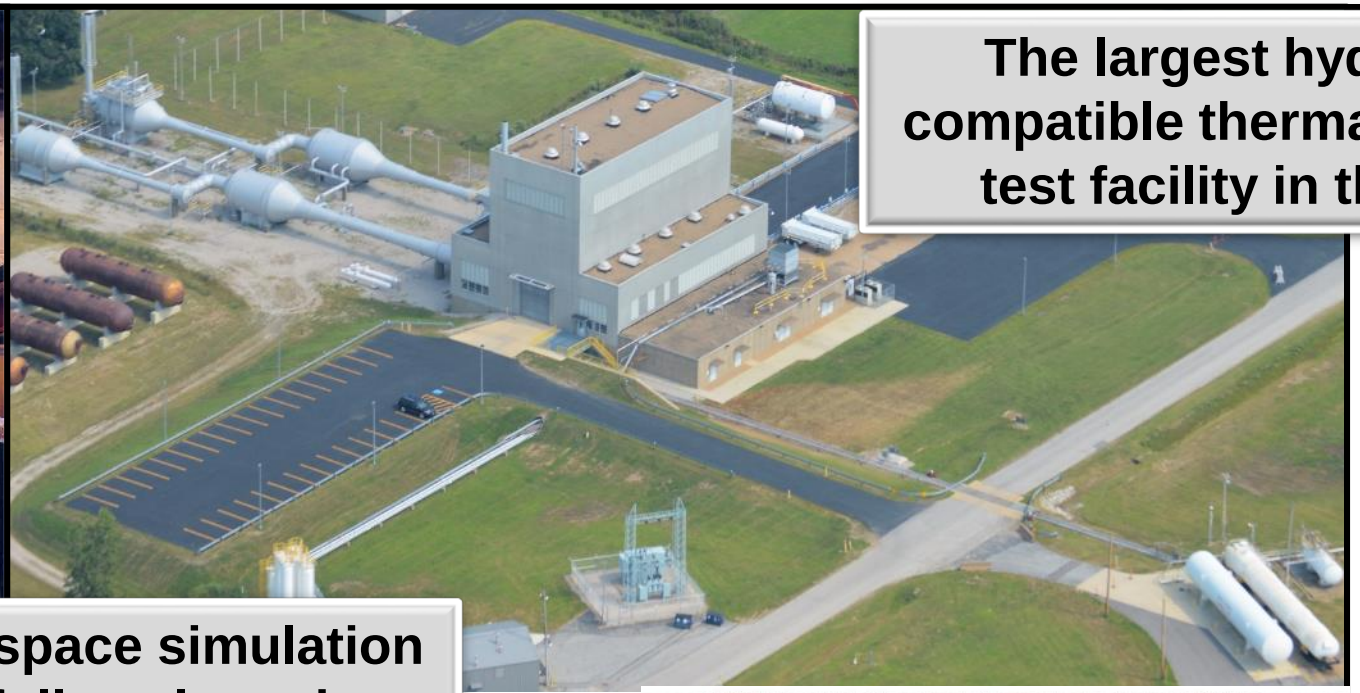
David E. Taylor, Deputy Director, Plum Brook Station

June 5, 2019

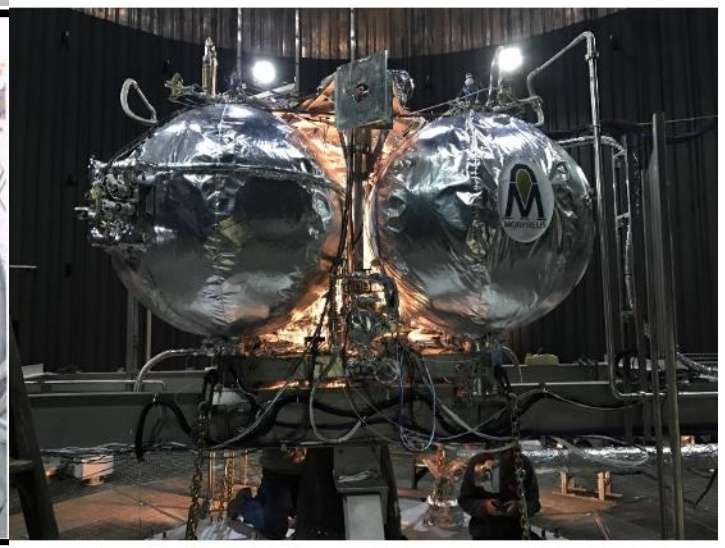
NASA Plum Brook Station In-Space Propulsion Facility





The largest hydrogen compatible thermal vacuum test facility in the U.S.

The world's largest space simulation facility capable of full-scale rocket engine and stage tests.



Past ISP Facility Tests

Altitude Hot Fire

Upper Stage Vehicles

Centaur

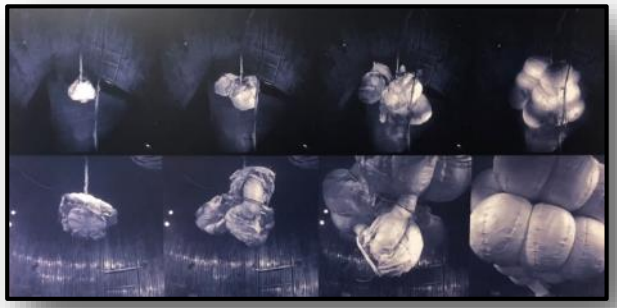
30k lbf (133 KN) Thrust

Delta III

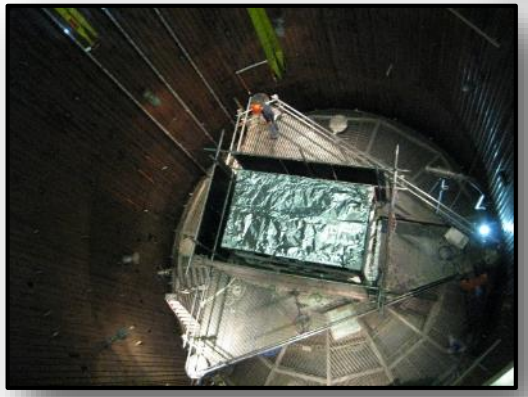
25k lbf (111 KN) Thrust

Thermal Vacuum

Mars Pathfinder
Lander Air Bag Inflation



Cryopanel Electric
Propulsion Demo



NASA SuperTIGER Balloon Experiment

and Many More

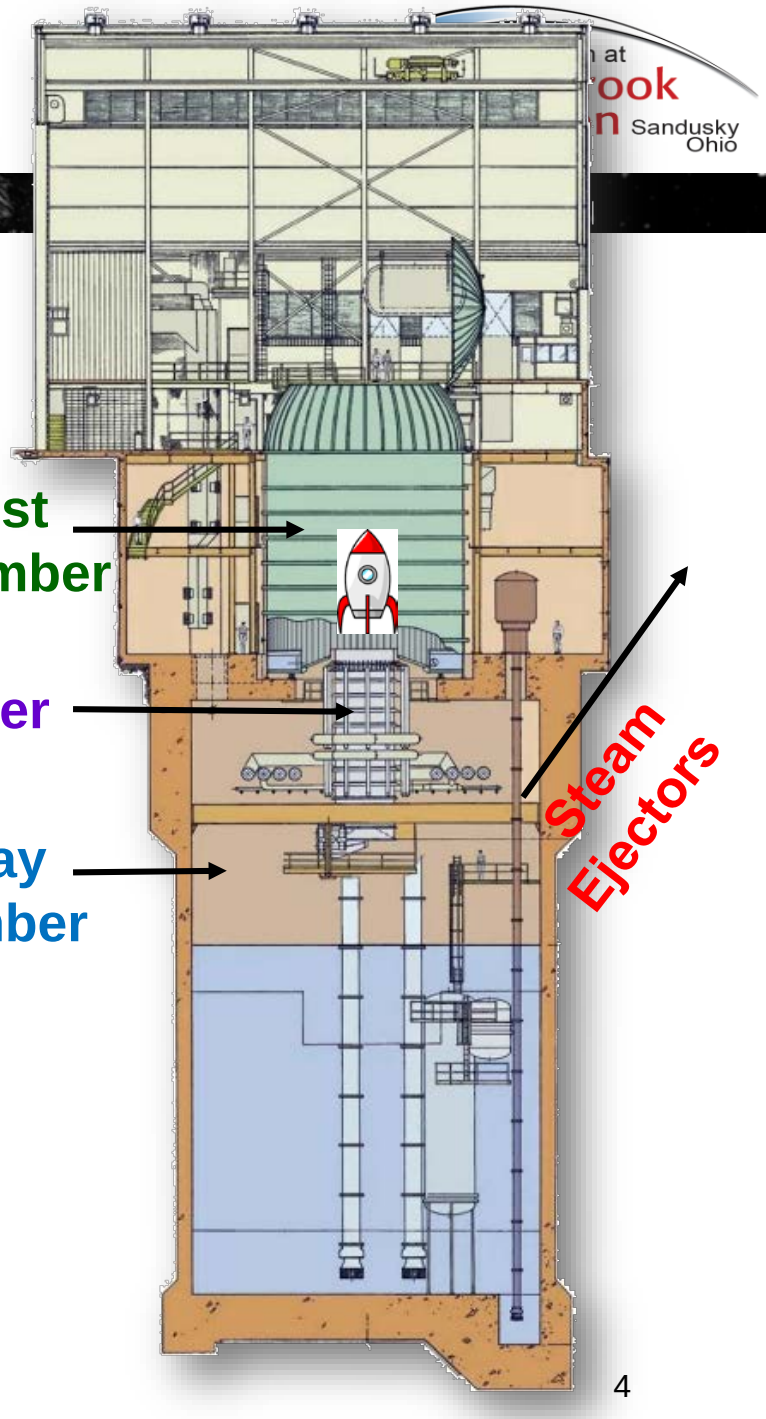
ISP Facility Baseline Capability Overview

Thermal Vacuum with Propellants Capability

- Capable of long duration space cold-soak and solar heating simulation
- Liquid hydrogen and liquid oxygen propellant storage and transfer systems

Altitude Hot Fire Capability

- Baselined for rocket engines with 100k lbf (440 KN) thrust for 300 seconds
  - Larger rocket engines supported for shorter durations
  - Smaller rocket engines support for longer durations
- Engine hot-fire at simulated 100k ft altitude (0.15 psia) (8 Torr)



ISP Facility Capability Status

Thermal Vacuum with Propellants Capability

Facility Subsystem	Status	Refurbishment
Vacuum Chamber	Fully Operational	2010
Liquid Nitrogen Heat Sink	Fully Operational	2011
Liquid Hydrogen System	Fully Operational	2012
Liquid Oxygen System	Fully Operational	2016

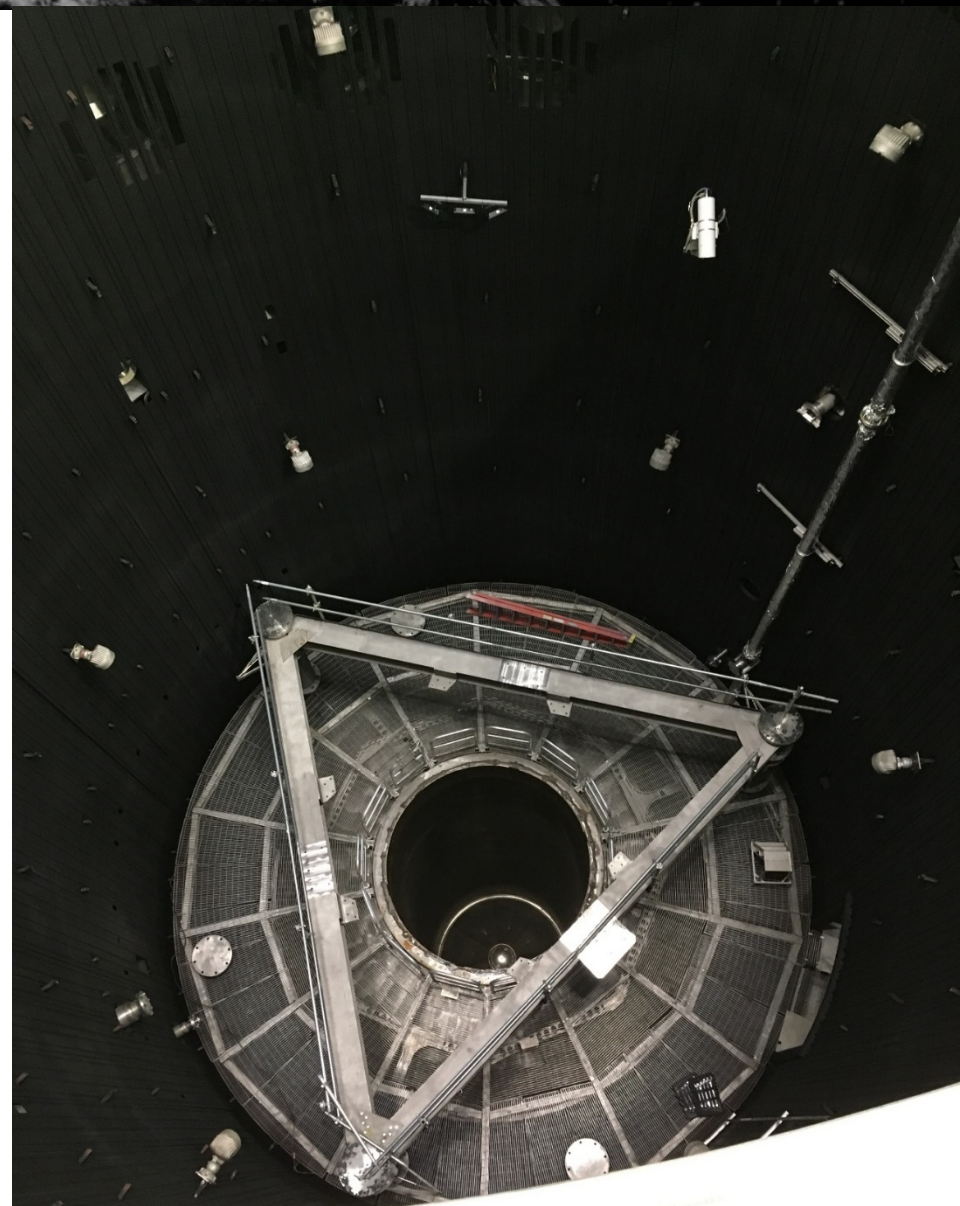
Altitude Hot Fire Capability

Facility Subsystem	Status	Refurbishment
Process Water System	Refurbishment	2019
Steam Ejectors	Refurbishment	2019

ISP Facility Thermal Vacuum Capability

Test Chamber and Liquid Nitrogen Heat Sink

- Dimensions: 38 ft (11.6 m) diameter
  62 ft (18.9 m) tall
- Vacuum chamber pressures as low as low as $5x10^{-8}$ Torr with the liquid nitrogen heat sink
- Copper fin and tube LN2 heat sink maintains temperature at -320°F (77 K)
- Thermal lamp array rotisserie heating (600 kW total)

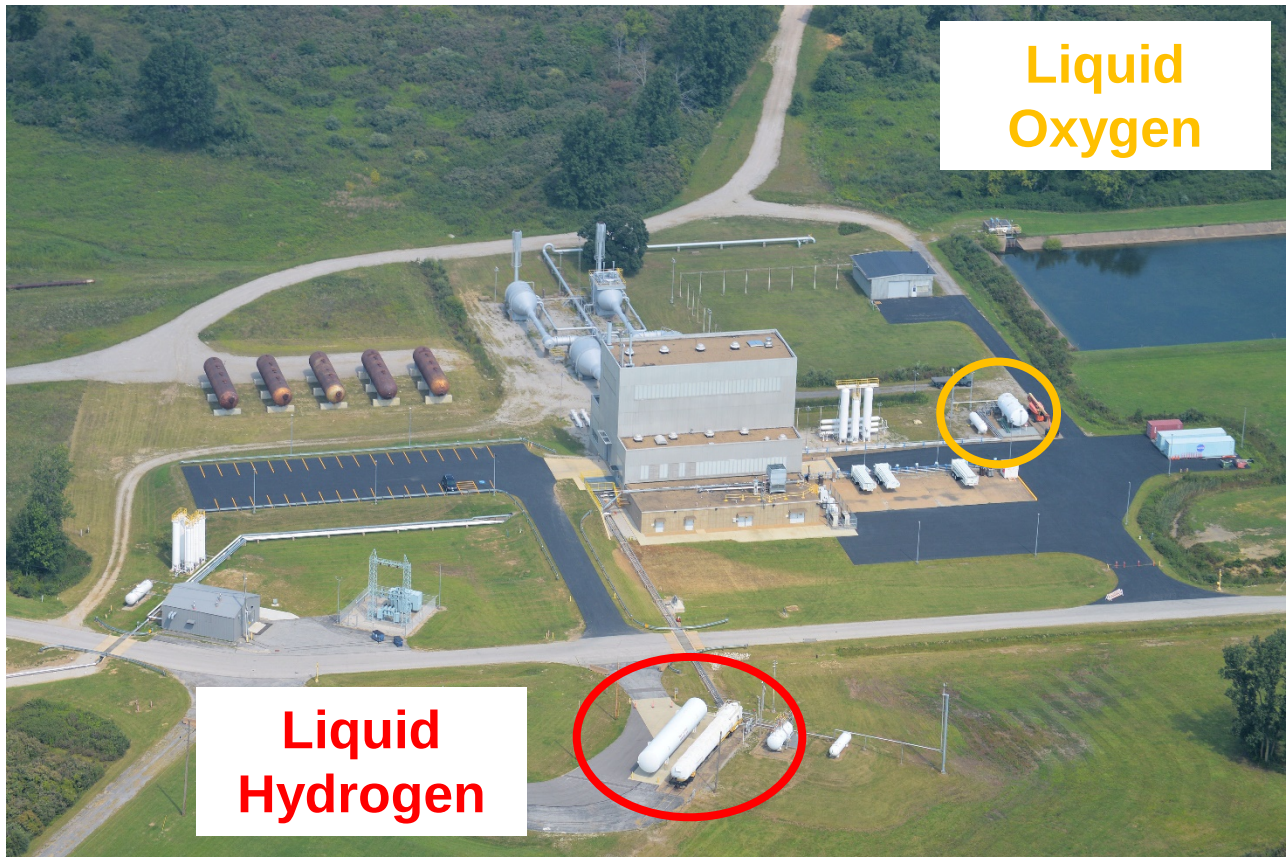


Fully Operational

ISP Facility Thermal Vacuum with Propellants

Propellant Storage and Delivery

- Liquid hydrogen onsite storage = 34,000 gallons
- Liquid oxygen onsite storage = 12,000 gallons
- Transfer systems to deliver propellants to test articles
- Vent systems (including low pressure vent)



Fully Operational

ISP Facility Altitude Hot Fire Capability

Process Water System

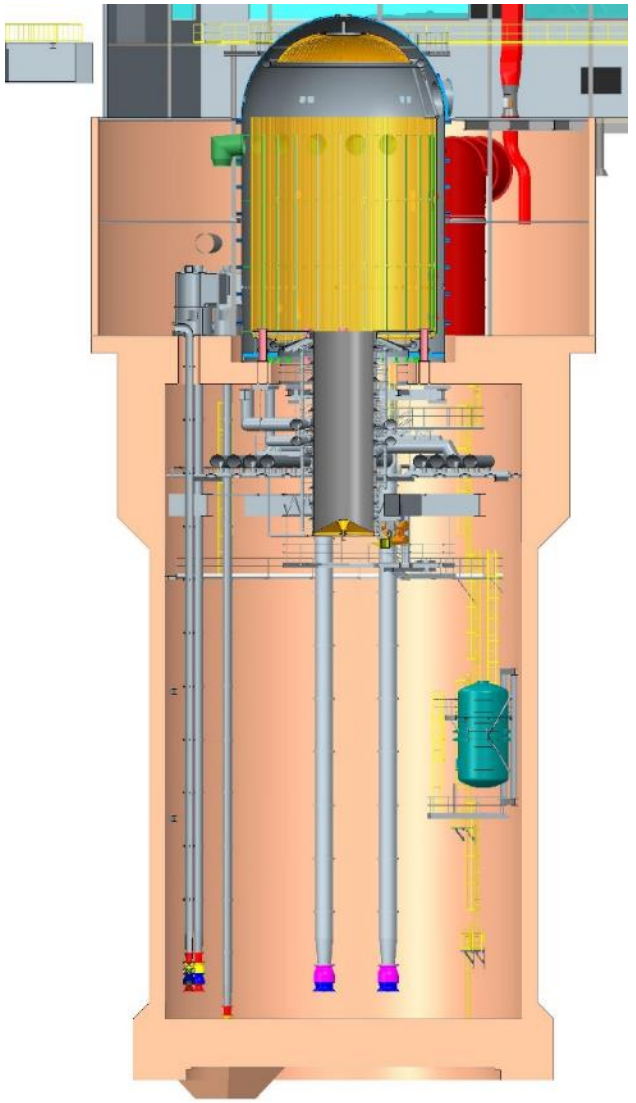
- Spray Chamber Dimensions: 67 ft (20.4 m) diameter x 120 ft (36.6 m) tall
- Water Capacity at 65 ft (19.8 m) depth: 1.7 million gallons (6.5 million liters)
- Four 2,000 HP (1,500 kW) recirculation pumps provide 225,000 gallons (851,000 liters) per minute to spray bars to cool rocket exhaust
- Three 1,000 HP (750 kW) pumps provide 40,000 gallons (151,000 liters) per minute to steam ejectors to condense exhaust steam

Refurbishment to be Completed in 2019

Process Water System Refurbishment

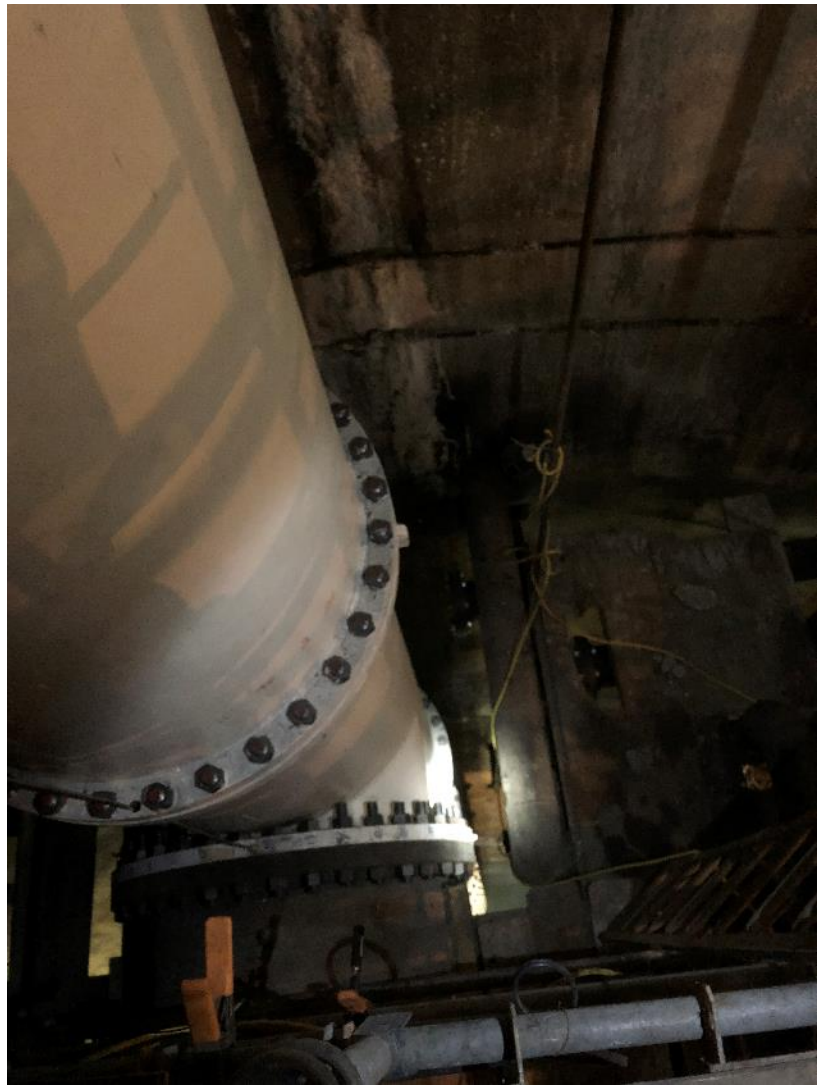
Four 2,000 HP Recirculation Pumps

- Pumps were seized due to corrosion buildup and bearing deterioration over time
- Removed from spray chamber, sent to OEM for refurbishment and reinstalled at the facility



Process Water System Refurbishment

Process Water System Refurbishment

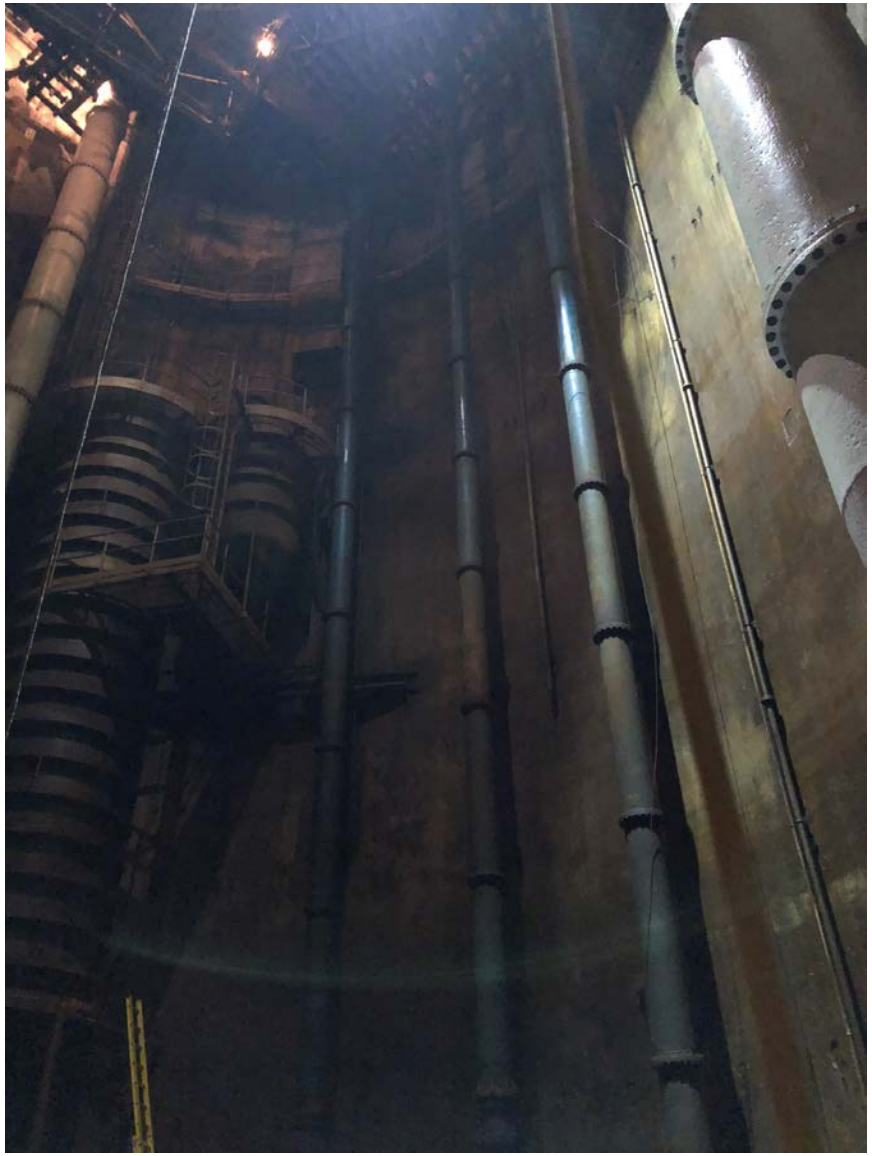


Process Water System Refurbishment

Three 1,000 HP Recirculation Pumps

- Pumps were seized due to corrosion buildup and bearing deterioration over time
- Removed from spray chamber, sent to OEM for refurbishment and reinstalled at facility
- Restore intercondenser and backside diffuser cooling nozzles

Process Water System Refurbishment



Process Water System Refurbishment

ISP Facility Altitude Hot Fire Capability

Steam Ejector System

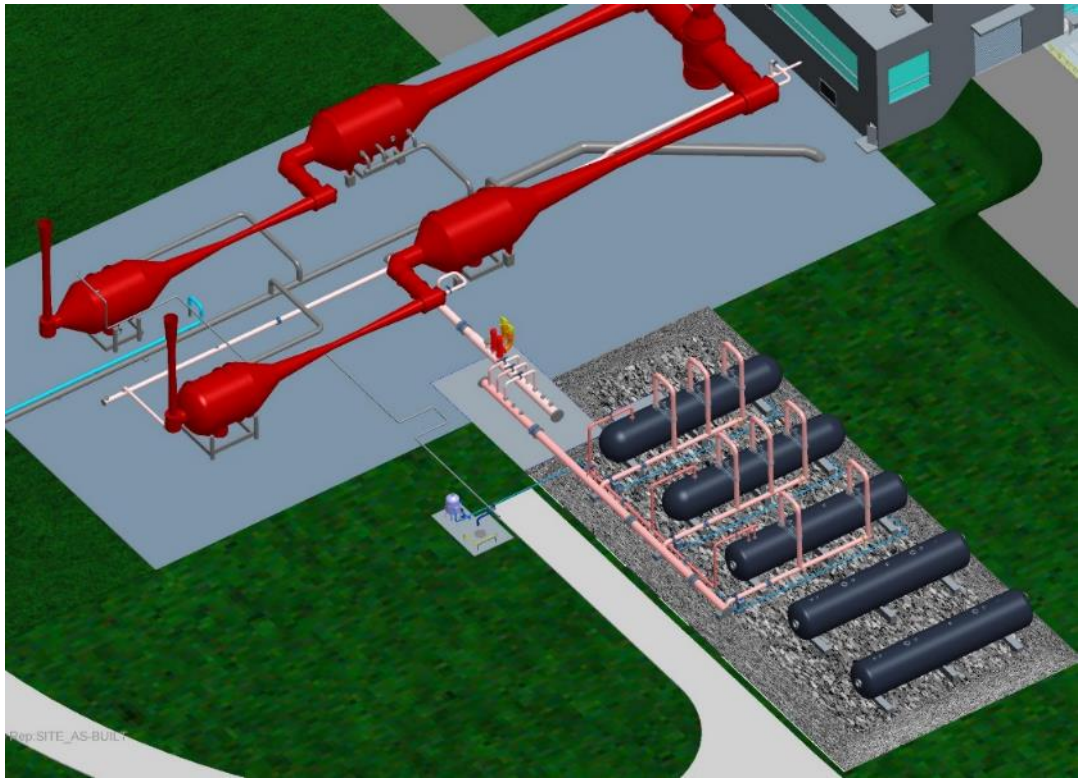
- Primary steam ejectors draw mostly non-condensable exhaust products from the spray chamber during hot fire
  - Two trains
  - Three stages each
  - 60 pound per second of steam per stage
  - 150 psig operating pressure
- Steam accumulator storage provides 300 seconds of operation of one primary steam ejector train
  - Five steam accumulators
  - Stores steam at 500 psig

Partial Refurbishment to be Completed in 2019

Steam Ejector System Refurbishment

Partial Steam System Refurbishment

- Restore one primary ejector train
- Restore three of five steam accumulators
- Provide steam with rental boiler equipment



Conclusion

- The U.S. has been without a large-scale thermal vacuum propulsion test capability for about 15 years.

- The current partial restoration of the ISP Facility exhaust systems will accommodate full-scale long duration cryogenic stage testing in a simulated space environment.
  - Hot fire testing altitudes up to 120,000 ft.
  - Reference baseline capability of 30,000 lbf thrust LOX/LH2 Stage with a 300 second run duration.

- This partially restored capability is the minimum required to accommodate known NASA test requirements
  - Increased capability requires restoration of additional accumulators and ejector train.

- First use of partially restored capability currently planned for 2020 (cryogenic stage hot-fire test).


Questions?